Carbon that counts

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Failing a cataclysmic collision with an asteroid or a volcanic explosion of earth-shattering proportions, the thin layer of weathered rock we call soil will have to feed 50% more people before this planet gets much older. The problem has not gone unnoticed. Learned men and women have gathered, books have been written and conferences convened. What has been discussed? How to build new topsoil? No. Everything but.

The collective knowledge of the human species on almost every subject from sub-atomic particles to distant galaxies is extraordinary, yet we know so little about soil. Is it too common, this world beneath our feet? This stuff of life that sustains us?

Failure to acknowledge/ observe/ measure/ learn how to rapidly build fertile topsoil may emerge as one of the greatest oversights of modern civilisation. Routine assessments of agricultural soils rarely extend beyond the top 10 to 15 centimetres and are generally limited to determining the status of a small number of elements, notably phosphorus (P) and nitrogen (N). Over-emphasis on these nutrients has masked the myriad of microbial interactions that would normally take place in soil; interactions that are necessary for carbon sequestration, precursor to the formation of fertile topsoil.

Fig. 1. In this paired site comparison, parent material, slope, aspect, rainfall and farming enterprise are the same. Levels of soil carbon in both paddocks were originally the same.

LHS: 0-50cm soil profile from a paddock in which groundcover has been actively managed (cropped and grazed) to enhance photosynthetic capacity.

RHS: 0-50cm soil profile from a conventionally managed neighbouring paddock (10 metres through the fence) that has been set-stocked and has a long history of phosphate application.

NOTES:

i) The carbon levels in the **0-10cm increment** are very similar. This surface carbon results from the decomposition of organic matter (leaves, roots, manure etc), forming short-chain **unstable 'labile'** carbon.

ii) The carbon **below 30cm** in the **LHS** profile has been sequestered via the **liquid carbon pathway** and rapidly incorporated into the humic (**non-labile**) soil fraction. Long-chain, non-labile carbon is **highly stable**.

Photo: Christine Jones
Property: 'Winona', operated by Colin and Nick Seis

Land management and soil carbon

The **RHS** soil profile in Fig.1 has formed under conventional grazing, intermittent cropping and standard practice fertiliser management. The soil profile on the **LHS** illustrates 50 centimetres of well-structured, fertile, carbon-rich topsoil that have formed as a result of the activation of the 'sequestration pathway' through pasture cropping and grazing management practices designed to maximise photosynthetic capacity. Superphosphate has not been applied to the **LHS** paddock for over thirty years. In the last 10 years the **LHS** soil has sequestered 164 t/ha of CO_2 (44.7 tC/ha). The sequestration rate in the last two years (2008-2010) has been 33 tonnes of CO_2 per hectare per year (9 tC/ha/yr).

Due to increased levels of soil carbon and the accompanying increases in soil fertility, the **LHS** paddock now carries **twice** the number of livestock as the **RHS** paddock.

Levels of both total and available plant nutrients, minerals and trace elements have dramatically improved in the **LHS** soil, due to solubilisation of the mineral fraction by microbes energised by increased levels of liquid carbon. In this positive feedback loop, sequestration enhances mineralisation which in turn enhances humification.

As a result, the rate of polymerisation has also increased, resulting in 78% of the newly sequestered carbon being non-labile. The stable, long-chain, high-molecular weight humic substances formed via the plant-microbe sequestration pathway cannot 'disappear in a drought'. Indeed, the humus now present in the **LHS** profile was formed against the back-drop of 13 years of below-average rainfall in eastern Australia.

A major cause of soil dysfunction, as illustrated in the **RHS** soil profile in Fig.1, is the removal of perennial groundcover for cropping and/or a reduction in the photosynthetic capacity of pastures due to inappropriate grazing management. In the post-war era, a range of chemical fertilisers have been applied to soils in an attempt to mask reduced soil function, but this approach has merely accelerated the process of soil carbon loss, particularly at depth. The net effect of soil structural decline has been compromised landscape function, particularly with respect to the storage and movement of water, losses of biodiversity, markedly reduced mineral levels in plants and animals and an increase in the incidence of metabolic diseases. This will no longer do.

Australia is not the only country in which subsoils - and hence landscape function - have deteriorated as a result of inappropriate land management and fertiliser practices. In New Zealand, a country blessed with vast tracts of inherently fertile topsoil, carbon losses are occurring at depth under heavily fertilised pastures, due to the inhibition of the sequestration pathway. To date, alternative management practices have been either dismissed or ignored by establishment science in that country.

It is important to note that the rapid improvements to soil fertility and soil function recorded in the **LHS** soil profile in Fig.1 are dependant on the enhanced photosynthetic capacity that accompanies regenerative forms of cropping and grazing management.

Not just any carbon - and not just anywhere

The soil surface increment, 0-10cm, generally contains the highest levels of short-chain, labile carbon, indicative of rapid turnover. While this 'active' carbon is important for the health of the soil food-web, the surface increment is not where one would be looking to safely 'store' atmospheric CO_2. The deeper in the soil profile that carbon is sequestered, and the more humified the carbon, the better.

Over the last 10 years, the amount of long-chain, non-labile soil carbon (ie the humic fraction) in the **LHS** profile has doubled in the 10-20cm increment, tripled in the 20-30cm increment and quadrupled in the 30-40cm increment. In future years, it is anticipated that the most rapid sequestration of stable soil carbon in this particular soil profile will take place in the 40-50cm increment, then later still, in the 50-60cm increment. That is, over time, fertile, carbon-rich topsoil will continue to build downwards into the subsoil.

Deeply sequestered carbon alleviates subsoil constraints, improves farm productivity, enhances hydrological function and improves mineral density in plants, animals and people.

The Kyoto Protocol, which relates only to carbon sequestered in the 0-30cm increment, completely overlooks this 'sequestration of significance' in the 30-60cm portion of the soil profile.

Building new topsoil

The formation of fertile topsoil can be breathtakingly rapid once the biological dots have been joined and the sequestration/ mineralisation/ humification pathway has been activated. The positive feedback loops render the liquid carbon pathway somewhat akin to perpetual motion. You can almost see new topsoil forming before your eyes.

The sun's energy, captured in photosynthesis and channelled from above-ground to below-ground as liquid carbon via plant roots, fuels the microbes that solubilise the mineral fraction. A portion of the newly released minerals enable rapid humification in deep layers of soil, while the remaining minerals are returned to plant leaves, facilitating an elevated rate of photosynthesis and increased levels of production of liquid carbon, which can in turn be channelled to soil, enabling the dissolution of even more minerals.

The levels of acid-extractable minerals in the **LHS** soil profile are higher than those on the **RHS** soil in the following proportions, calcium 177%, magnesium 38%, potassium 46%, sulphur 57%, phosphorus 51%, zinc 86%, iron 22%, copper 102%, boron 56%, molybdenum 51%, cobalt 79% and selenium 17%.

Levels of water-soluble plant nutrients have increased to a similar extent.

Where do the 'new' minerals come from?

A standard soil test provides very little information about the bulk soil and the minerals potentially available to plants. Most lab reports list 'plant-available' nutrients (that is, nutrients not requiring microbial intermediaries for plant access) and if requested, acid-extractable minerals (misleadingly quoted as 'totals').

With respect to phosphorus, for example, the 'plant-available' levels are usually estimated using an Olsen, Colwell, Bray 1, Bray 2, Mehlich 1, Mehlich 3 or Morgan P test. These tests provide information on the relatively small pools of inorganic soil P. Where a figure for Total P is provided, it refers only to the quantity of P that is acid-extractable, not the actual 'total' amount of P in the soil.

Other techniques, such as x-ray fluorescence (XRF) are required to determine the composition of the insoluble, acid-resistant mineral fraction, which comprises 96-98% of the soil mass and contains far more minerals than are shown in a standard soil test.

Indeed, the top one metre of soil contains thousands of tonnes of minerals per hectare. Specific functional groups of soil microbes have access to this mineral fraction, while others are able to fix atmospheric N, provided they receive liquid carbon from plants.

The newly accessed minerals, particularly iron and aluminium, plus the newly fixed N, (48% more Total N in the LHS soil profile), enable rapid humification of labile carbon. However, the liquid carbon needed to drive the process will not be forthcoming if high analysis N and/or P fertilisers inhibit the formation of a plant-microbe bridge.

The 'classic' models for soil carbon dynamics, based on data collected from set-stocked conventionally fertilised pastures and/or soil beneath conventionally fertilised annual crops, where the plant-microbe bridge is dysfunctional, fail to include nutrient acquisition from the bulk mineral fraction and associative N-fixation, hence cannot explain rapid topsoil formation at depth. The puzzle is that establishment science clings to these out-dated models, inferring real-life data to be inconsequential. Measurements made outside of institutionalised science are generally branded 'anecdotal' and largely ignored.

Making the world a better place

When pastures, diverse cover crops and crops sown into pastures are managed to utilise nature's free gifts - sunlight, air and soil microbes - to rapidly form new, fertile, carbon-rich topsoil, the process is of immense benefit, not only to individual farmers, but to rural communities around the globe.

Property owner, Colin Seis, has no wish to revert to former management practices, as he can now carry twice the number of stock at a fraction of the cost. Nevertheless, if the land management were to change for some unforeseeable reason, the increased levels of humus (non-labile carbon) now present in his soil would remain for considerably longer than the average lifespan of carbon in trees.

In addition to reducing levels of atmospheric carbon dioxide, the activation of the soil sequestration pathway results in the release of plant nutrients from the theoretically insoluble mineral fraction, which comprises by far the largest proportion (96-98%) of the soil mass. This increased mineral availability improves the health of pastures, crops, livestock and the people consuming agricultural produce. Everyone benefits when food is more nourishing.

Mineral availabilities are determined more by the rate of carbon flow from plants than by the stock of carbon in the soil. The 'key' to mineral management is appropriate groundcover management. When the plant-soil sequestration pathway has been activated, it is possible to feed more people from less land.

Taking action on soil carbon

Those who persist in maintaining that soil carbon comes at a 'cost' and/or disappears during a drought and/or requires applications of expensive fertiliser and/or necessitates forgone production - had better 'please explain'. The on-farm reality is that when the sequestration pathway for non-labile carbon has been activated, the opposite is true.

How much longer will the farming community have to endure the myths, misconceptions and misleading models put forward by the people currently employed to solve the problem of declining soil carbon, dwindling soil fertility and losses in soil function?

Will policy-makers show some initiative, seek the truth and act on it?

'Winona' data summary

2000-2010: 164 tonnes CO_2 sequestered per hectare (44.7 tC/ha).
2008-2010: Sequestration rate 33 tonnes CO_2 per hectare per year (9 tC/ha/yr).
Permanence: 78% of the newly sequestered carbon is in the non-labile (humic) fraction of the soil - rendering it highly stable.
Location: The greatest increases in soil carbon have occurred at depth, overcoming subsoil constraints. Non-labile soil carbon has doubled in the 10-20cm increment, tripled in the 20-30cm increment and quadrupled in the 30-40cm increment.
Nitrogen: An extra 2t/ha (48% increase) in Total N, which would not be possible unless associative N-fixing bacteria were being supported via the liquid carbon pathway.
Minerals: The following increases in soil minerals have occurred - calcium 177%, magnesium 38%, potassium 46%, sulphur 57%, phosphorus 53%, zinc 86%, iron 22%, copper 102%, boron 56%, molybdenum 51%, cobalt 79% and selenium 17%.
Cash benefit: At a carbon price of $20 per tonne, and assuming payment for non-labile (stable) carbon only, the value of the sequestration of 33 tCO_2/ha/yr would be $660 x 78% = $515/ha/yr.
A price on non-labile soil carbon would provide worthwhile incentive for progressive farmers to rebuild our precious agricultural soils.